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# EVALUATION OF MINIATURE VACUUM ULTRAVIOLET LAMPS FOR STABILITY AND OPERATING CHARACTERISTICS

FINAL REPORT

LYMAN-ALPHA TASK

Contract No. NAS8-35812

January 22, 1985

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## 1.0 INTRODUCTION

This report documents the effort expended by Radiometrics, Inc. under Contract NAS8-35812 in performing the initial phase of modifications required to change the near ultraviolet source in the Optical Contamination Monitor to a source with output at or near the Lyman-alpha hydrogen line. The effort consisted of selecting, acquiring and testing candidate miniature ultraviolet lamps with significant output in or near 121.6 nm. The effort also included selection of a miniature dc high-voltage power supply capable of operating the lamp. The power supply was required to operate from available primary power supplied by the Optical Effect Module (OEM) and it should be flight qualified or have the ability to be qualified by the user.

## 2.0 EQUIPMENT EVALUATED

The following items were selected from a small group of available lamps and power supplies that generally met the requirements and objectives of this effort. Nothing was found that was already flight qualified. The items below were selected for further testing.

- o Vacuum Ultraviolet Lamp, Scientific Services Co., Rocky Hill, N.J., Model 108, 10.0 eV, Krypton Filled, Qty. 3.
- o Vacuum Ultraviolet Lamp, Scientific Services Co., Rock Hill, N.J., Model 108, 10.2 eV plus continuum, Hydrogen Filled Qty. 1.
- o DC High-voltage Power Supply, Mil Electronics, Inc., Lowell, Mass., Model 3S81600, Qty. 1.

## 3.0 DESCRIPTION OF TEST

Miniature ultraviolet lamps were subjected to a series of tests to determine operating characteristics and starting voltage for a temperature range of 0 to 70 degrees Centigrade. The candidate lamps were powered by a dc source which was also being tested under the same conditions for compatibility with the lamp and suitability for installation in the OEM.

### 3.1 Starting Voltage Test

The starting voltage test schematic is shown in Figure 1. The lamp under test and its dc power supply were placed inside an environmental chamber capable of creating and maintaining a specified temperature environment in the range of 0 to 70 degrees Centigrade. A 1.1 megohm resistor was connected in series with the lamp and power supply to limit current when the gas discharge occured. A 1000 ohm resistor was also connected in series with

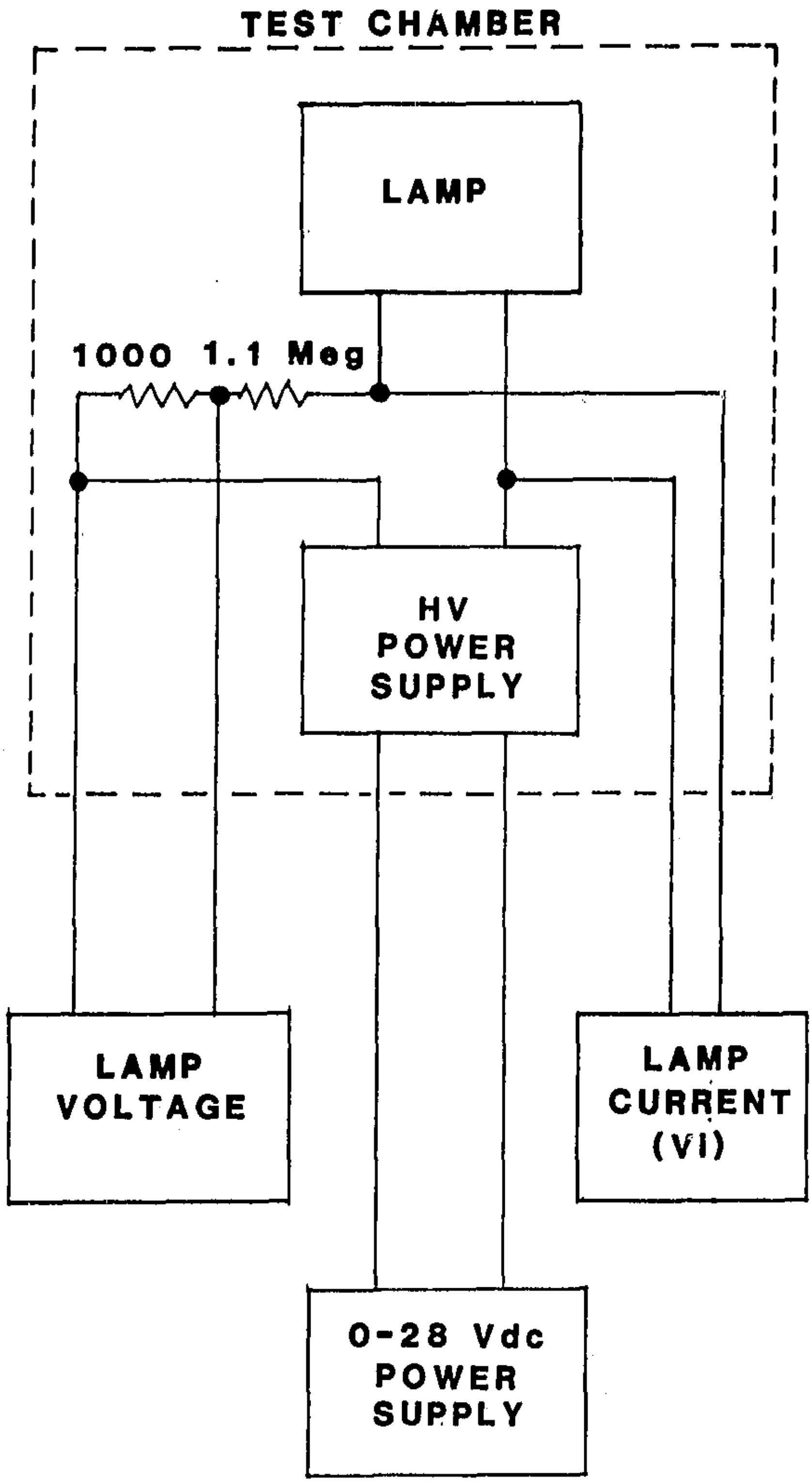


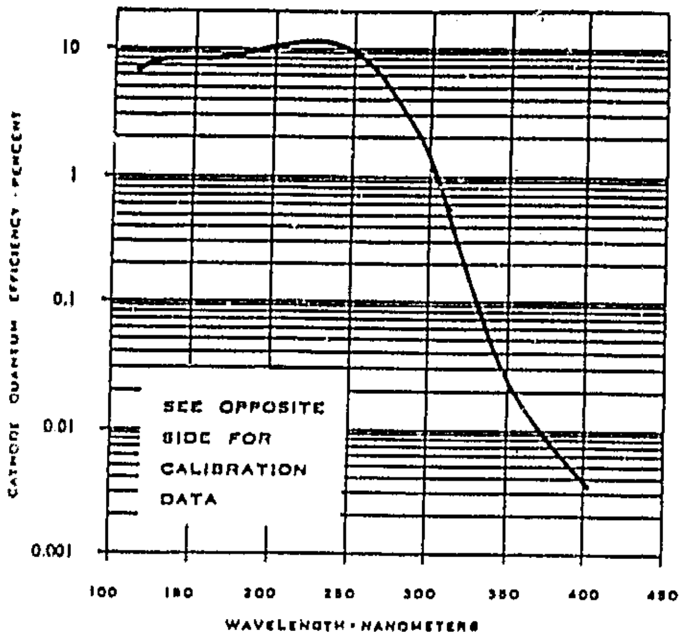

**Figure 1. Starting voltage test diagram.**

the lamp and power supply to monitor current through the lamp. A digital voltmeter was connected across the lamp terminals to monitor the voltage up to the point where the gas discharge produced a visible glow inside the lamp. A differential voltmeter was connected across the 1000 ohm resistor to monitor current through the lamp. Primary power was supplied by a variable voltage dc power supply located outside the test chamber.

The test procedure consisted of bringing the test chamber to the desired temperature and letting the equipment "soak" for a period of time before taking data. Starting voltage was determined by beginning with zero volts applied to the input of the high-voltage power supply, and then slowly increaseing the voltage while observing the voltage applied to the lamp and the lamp for the first signs of the glow discharge. When the discharge was noted the highest lamp voltage observed was recorded as the starting voltage. Because of the statistical nature of the exact starting voltage, this procedure was repeated five times for each temperature to get a better indication of the value to be expected. The high-voltage power supply was only required to be functional during this test.

## 3.2 Operating Characteristics

Operating characteristics were determined over a temperature range of 0 to 70 degrees Centigrade similar to the test for starting voltage. For this test the lamp, high-voltage power supply and a vacuum photodiode were placed in the test chamber. The lamp was operated at typical voltage and current as specified by the manufacturer. Lamp voltage, current and light output were measured for each temperature setting. The photodiode used to monitor the light output was an EMR Model 543P-09-00 having a spectral response as shown in Figure 2. Although the photodiode was capable of detecting the spectral output at the Lyman-alpha line of interest, no attempt was made to isolate the lamp's output to just that region of the spectrum. To measure the lamp's spectral output near the 121.6 nm Lyman-alpha line would require a monochromator and test chamber that could be evacuated or at least purged to reduce the absorption caused by air. The main objective of this test was to determine if the lamps were stable over a period of time when held at a constant temperature and if they would operate reliably at the temperatures of interest.




QUALITY ASSURANCE APPROVAL

R. Marciano ...... Date 2-14-75

# CALIBRATION PHOTODIODE SPECIFICATION

MODEL 543P-09-00 SERIAL NO. 21966

**PHOTOCATHODE CHARACTERISTICS***

| Wavelength Nanometers | Radiant Sensitivity $\times 10^{-3}$ A/W | Quantum Efficiency % |
|---|---|---|
| 121.6 | 7.3 | 7.5 |
| 253.7 | 19.0 | 9.3 |
| 365.0 | .032 | .011 |

*Measured at 25 °C

See curve for complete spectral characteristic.

Anode leakage at 150 VDC $6 \times 10^{-13}$

**MAXIMUM RATINGS**

Supply voltage 400 Volts

Anode current $1.0 \times 10^{-7}$ Amps

Temperature 100 °C

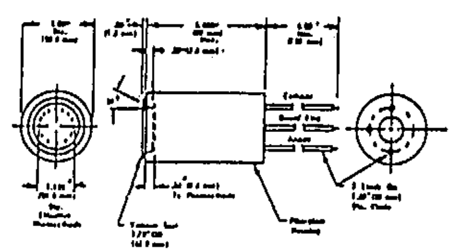
EMR Schlumberger

EMR PHOTOELECTRIC
BOX 44
PRINCETON, NEW JERSEY 08540

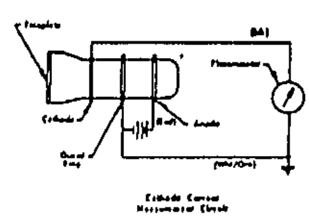
EMR DIVISION OF WESTON INSTRUMENTS, INC.

MODEL NO. 543P-09-00 SERIAL NO. 21966 DATE 2-14-75

| WAVELENGTH NANOMETERS | RADIANT SENSITIVITY $\times 10^{-3}$ A/W | QUANTUM EFFICIENCY % |
|---|---|---|
| 116.4 | 6.2 | 6.6 |
| 121.6 | 7.3 | 7.5 |
| 135.4 | 8.2 | 7.9 |
| 148.7 | 9.9 | 8.3 |
| 160.8 | 10.1 | 7.8 |
| 170.0 | 11.1 | 8.1 |
| 182.9 | 13.8 | 9.4 |
| 206.7 | 18.5 | 11.1 |
| 221.4 | 21.9 | 12.3 |
| 229.6 | 22.6 | 12.2 |
| 253.7 | 19.0 | 9.3 |



OUTLINE DRAWING



WIRING DIAGRAM

NOTES:
1. Do not operate at intermediate pressures between $1 \times 10^{-3}$ - $10^{2}$ Torr.
2. Protect $MgF_2$ window from scratches and contamination by vacuum pump oils, etc.
3. If cleaning of the window is NECESSARY, use acetone or freon.
4. Keep case in dry area for storage.
5. Calibrated with 8 mm x 2 mm slit, centered axially on photocathode, in line with fiducial mark.

**Figure 2. Photodiode spectral response.**

Figure 3 is a schematic diagram of the lamp and photodetector circuit used for the test. Lamp voltage and current are monitored as in the starting voltage test of Section 3.1. The photodiode was located inside the test chamber to keep the optical path short and thereby reduce the absorption of lamp output by air molecules. A dc-dc power supply was used to provide 147 Vdc bias for the photodiode. It was located outside the test chamber. The low level anode current of the photodiode was converted to a readily measurable voltage by a current-to-voltage amplifier that was also located outside of the chamber. The amplifier output voltage was measured with a digital voltmeter. The gain factor for the amplifier output was -22 millivolts per nanoampere.

The test procedure consisted of setting the desired temperature inside the test chamber, allowing a period of time for the equipment inside to "soak", and then recording the temperature, lamp voltage, lamp current and photodiode output. Time of day and the date were recorded to establish the time between readings.

### 3.3 High-Voltage Power Supply

The high-voltage power supply used to operate the lamps for all the tests was a miniature 3-watt dc-dc 100% encapsulated unit Manufactured by Mil Electronics Inc., of Lowell, Mass. The power supply was being evaluated along with the lamps as a possible replacement for the ac power supply currently used in the Optical Contamination Monitor. No problems were encountered with the unit during the tests. This particular unit was supplied with a silicone rubber encapsulant that would not be acceptable for use in the OEM because of the encapsulant. The manufacturer will supply this model without encapsulant for applications where a special material is required. The user may add the proper encapsulanting material for his application.

## 4.0 TEST DATA

Tables 1 through 8 contain all the raw test data collected during the lamp evaluations. Tables 1 through 4 contain the starting voltage data for the four lamps evaluated. Tables 5 through 8 contain the operating data. Column headings correspond to the measurements indicated on the schematic diagrams of Figures 1 and 3 with one exception. LAMP SUPPLY voltage is calculated from the LAMP VOLTAGE reading and the voltage drop across the 1.1 megohm and 1000 ohm resistors. Lamp current is the voltage Vi divided by 1000.

The first two runs in each table were made at room temperature to set the lamp current and check the instrumentation before the test chamber was turned on. No attempt was made to operate each lamp at a specific current or over a range of currents. The lamp current setting was arbitrary, but was selected to be well within the manufacturer's recommended operating range. The primary

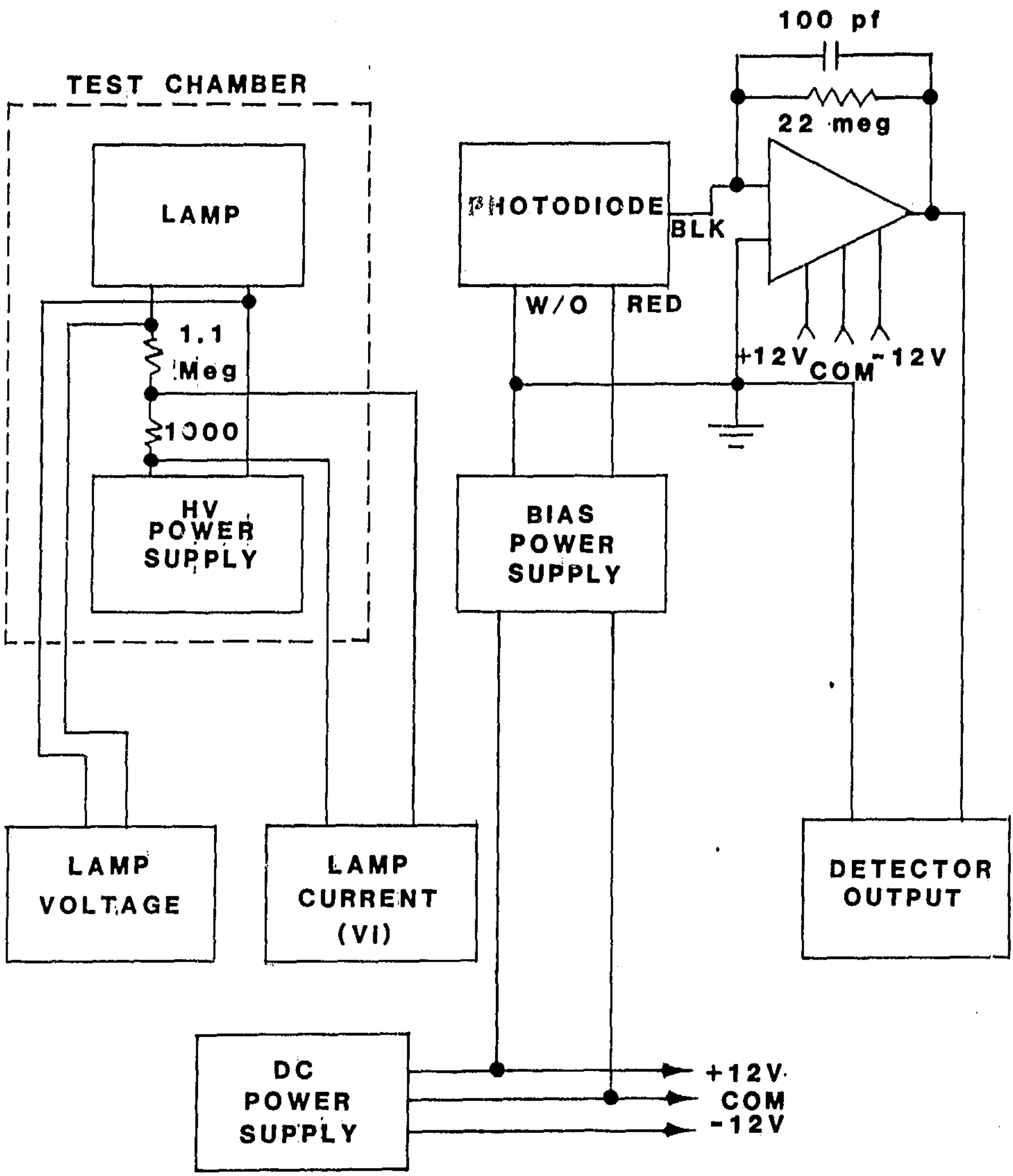



Figure 3. Operating characteristics test diagram.

concern was short term stability where the time interval was no more than five minutes. Each run was monitored for considerably more than five minutes in the interest of acquiring comprehensive data to establish the lamp's stability at constant temperature.

## 5.0 TEST EQUIPMENT

The following items of test equipment were used to perform the tests described in this report.

- o Environmental Test Chamber, Delta Design, Model 6400
- o Differential Voltmeter, John Fluke Co., Model 873A, SN 132
- o Digital Voltmeter, Beckman Instruments, Model 3020, SN 20416066
- o Digital Voltmeter, Beckman Instruments, Model 3030, SN 91116298
- o Photodiode, EMR Model 543P-09-00, SN 21966
- o DC Power Supply, Hewlett Packard, Model 6216A, SN 1141A12978
- o DC Power Supply, Endicott Research Group, Model E715-215R
- o DC Power Supply, Power Designs, Model TP325
- o Current-to-Voltage Amplifier, Radiometrics, Inc., Type TL071

## 6.0 RESULTS AND CONCLUSIONS

All of the lamps tested operated satisfactorily over the temperature range of 0 to 70 degrees Centigrade. There were no problems with excessive changes in starting voltage as the temperature was varied over the range of interest. The highest starting voltage recorded was 1118 volts. Generally, the lamps fired at about 1000 volts or below. A power supply capable of producing at least 1500 volts dc will produce reliable starting.

The lamp's output does change with temperature as expected, however, for this application it doesn't cause a problem. Short term stability during the actual measurement sequence is the primary consideration. After the temperature has stablized the lamp output is also stable over a interval greater than five minutes. This should be more than adequate stability for an accurate measurement cycle by the contamination monitor.

Further testing is required to establish operating lifetime, reliability and tolerance to vibration before it can be qualified for flight applications. Detailed examination of the spectral emission in the Lyman-alpha region is needed to fully characterize the lamp output and assess its suitability for the contamination monitor application.

TABLE 1. LAMP STARTING VOLTAGE

| RUN # | LAMP (eV) | SN | STARTING VOLTAGE (Volts) | TEMP. (°C) | REMARKS |
|---|---|---|---|---|---|
| 1 | 10.0 | 2125 | 764 | 0 | 10-16-84 |
| 2 | | | 775 | | |
| 3 | | | 765 | | |
| 4 | | | 820 | | |
| 5 | | | 758 | | |
| 1 | | | 908 | 25 | |
| 2 | | | 916 | | |
| 3 | | | 902 | | |
| 4 | | | 889 | | |
| 5 | | | 917 | | |
| 1 | | | 970 | 50 | |
| 2 | | | 992 | | |
| 3 | | | 1011 | | |
| 4 | | | 1023 | | |
| 5 | | | 1005 | | |
| 1 | | | 899 | 70 | |
| 2 | | | 957 | | |
| 3 | | | 970 | | |
| 4 | | | 962 | | |
| 5 | | | 976 | | |

TABLE 2. LAMP STARTING VOLTAGE

| RUN # | LAMP (eV) | SN | STARTING VOLTAGE (Volts) | TEMP. (°C) | REMARKS |
|---|---|---|---|---|---|
| 1 | 10.0 | 2127 | 730 | 0 | 10-17-84 |
| 2 | | | 742 | | |
| 3 | | | 751 | | |
| 4 | | | 744 | | |
| 5 | | | 746 | ↓ | |
| 1 | | | 1011 | 25 | |
| 2 | | | 1039 | | |
| 3 | | | 1082 | | |
| 4 | | | 1069 | | |
| 5 | | | 1101 | ↓ | |
| 1 | | | 1034 | 50 | |
| 2 | | | 1085 | | |
| 3 | | | 1111 | | |
| 4 | | | 1106 | | |
| 5 | | | 1118 | ↓ | |
| 1 | | | 1010 | 70 | |
| 2 | | | 1063 | | |
| 3 | | | 1084 | | |
| 4 | | | 1092 | | |
| 5 | ↓ | ↓ | 1094 | ↓ | ↓ |

TABLE 3. LAMP STARTING VOLTAGE

| RUN # | LAMP (eV) | SN | STARTING VOLTAGE (Volts) | TEMP. (°C) | REMARKS |
|---|---|---|---|---|---|
| 1 | 10.2 | 2129 | 785 | 0 | 10-23-84 |
| 2 | | | 783 | | |
| 3 | | | 789 | | |
| 4 | | | 788 | | |
| 5 | | | 783 | | |
| 1 | | | 812 | 25 | 10-17-84 |
| 2 | | | 795 | | |
| 3 | | | 783 | | |
| 4 | | | 794 | | |
| 5 | | | 787 | | |
| 1 | | | 859 | 50 | |
| 2 | | | 839 | | |
| 3 | | | 814 | | |
| 4 | | | 827 | | |
| 5 | | | 819 | | |
| 1 | | | 834 | 70 | |
| 2 | | | 876 | | |
| 3 | | | 845 | | |
| 4 | | | 884 | | |
| 5 | | | 830 | | |

TABLE 4. LAMP STARTING VOLTAGE

| RUN # | LAMP (eV) | SN | STARTING VOLTAGE (Volts) | TEMP. (°C) | REMARKS |
|---|---|---|---|---|---|
| 1 | 10.0 | 1933 | 950 | 0 | 10-23-84 |
| 2 | | | 938 | | |
| 3 | | | 936 | | |
| 4 | | | 937 | | |
| 5 | | | 943 | | |
| 1 | | | 826 | 25 | 10-18-84 |
| 2 | | | 919 | | |
| 3 | | | 921 | | |
| 4 | | | 925 | | |
| 5 | | | 927 | | |
| 1 | | | 866 | 50 | |
| 2 | | | 934 | | |
| 3 | | | 938 | | |
| 4 | | | 931 | | |
| 5 | | | 938 | | |
| 1 | | | 985 | 70 | |
| 2 | | | 991 | | |
| 3 | | | 987 | | |
| 4 | | | 966 | | |
| 5 | | | 1005 | | |

TABLE 5. LAMP OPERATING CHARACTERISTICS

Lamp: Scientific Services, 10.0 eV, SN 2125

| RUN # | TEMP. (C°) | Vi (Volts) | LAMP SUPPLY (Volts) | LAMP VOLTAGE (Volts) | DET. BIAS (Volts) | DET. OUTPUT (Volts) | TIME OF MEAS. | DATE |
|---|---|---|---|---|---|---|---|---|
| 1 | 22 | .598 | 964 | 306 | 146 | - .034 | 9:23 | 11-01-84 |
| 2 | 22 | .598 | 964 | 306 | ↓ | - .034 | 9:46 | ↓ |
| 1 | 0 | .598 | 968 | 310 | | - .023 | 11:16 | |
| 2 | 0 | .598 | 968 | 310 | | - .023 | 12:53 | |
| 3 | 0 | .598 | 968 | 310 | | - .022 | 1:58 | |
| 4 | 20 | .598 | 965 | 307 | | - .030 | 3:15 | |
| 5 | 20 | .598 | 965 | 307 | | - .027 | 4:15 | |
| 6 | 20 | .598 | 965 | 307 | | - .027 | 5:02 | |
| 7 | 25 | .598 | 965 | 307 | | - .029 | 9:35 | 11-02-84 |
| 8 | 25 | .598 | 965 | 307 | | - .030 | 10:15 | ↓ |
| 9 | 25 | .598 | 965 | 307 | | - .028 | 11:30 | |
| 10 | 50 | .580 | 947 | 308 | | - .050 | 2:45 | |
| 11 | 50 | .580 | 947 | 308 | | - .053 | 3:30 | |
| 12 | 50 | .580 | 947 | 308 | | - .054 | 4:15 | |
| 13 | 70 | .526 | 895 | 316 | | - .101 | 9:05 | 11-05-84 |
| 14 | 70 | .518 | 895 | 316 | | - .092 | 9:50 | ↓ |
| 15 | 70 | .504 | 895 | 316 | | - .100 | 11:00 | |

TABLE 6. LAMP OPERATING CHARACTERISTICS

Lamp: Scientific Services, 10.0 eV, SN 1933

| RUN # | TEMP. (C°) | Vi (Volts) | LAMP SUPPLY (Volts) | LAMP VOLTAGE (Volts) | DET. BIAS (Volts) | DET. OUTPUT (Volts) | TIME OF MEAS. | DATE |
|---|---|---|---|---|---|---|---|---|
| 1 | 20 | .543 | 956 | 358 | 147 | - .032 | 9:00 | 11-08-84 |
| 2 | 20 | .543 | 955 | 357 | | - .033 | 9:15 | |
| 1 | 0 | .552 | 956 | 348 | | - .010 | 11:00 | |
| 2 | 0 | .552 | 954 | 346 | | - .010 | 11:40 | |
| 3 | 0 | .558 | 952 | 338 | | - .012 | 3:10 | |
| 4 | 20 | .553 | 950 | 341 | | - .007 | 3:55 | |
| 5 | 20 | .555 | 950 | 339 | | - .018 | 8:50 | |
| 6 | 20 | .555 | 949 | 338 | | - .019 | 9:30 | |
| 7 | 25 | .560 | 947 | 330 | | - .008 | 1:50 | |
| 8 | 25 | .560 | 947 | 330 | | - .008 | 2:30 | |
| 9 | 25 | .551 | 947 | 340 | | - .009 | 9:30 | |
| 10 | 50 | .546 | 939 | 338 | | - .012 | 10:30 | |
| 11 | 50 | .546 | 938 | 337 | | - .009 | 11:15 | |
| 12 | 50 | .545 | 931 | 331 | | - .014 | 10:15 | |
| 13 | 70 | .521 | 911 | 337 | | - .006 | 10:55 | |
| 14 | 70 | .517 | 905 | 336 | | - .008 | 11:30 | |
| 15 | 70 | .513 | 901 | 336 | | - .009 | 12:00 | |

TABLE 7. LAMP OPERATING CHARACTERISTICS

Lamp: Scientific Services, 10.0 eV, SN 2127

| RUN # | TEMP. (C°) | Vi (Volts) | LAMP SUPPLY (Volts) | LAMP VOLTAGE (Volts) | DET. BIAS (Volts) | DET. OUTPUT (Volts) | TIME OF MEAS. | DATE |
|---|---|---|---|---|---|---|---|---|
| 1 | 22 | .544 | 905 | 306 | 147 | - .025 | 2:00 | 11-15-84 |
| 2 | 22 | .544 | 905 | 306 | | - .025 | 2:30 | |
| 1 | 0 | .544 | 904 | 308 | | - .010 | 3:15 | |
| 2 | 0 | .542 | 905 | 308 | | - .012 | 9:00 | |
| 3 | 0 | .542 | 905 | 308 | | - .013 | 9:30 | |
| 4 | 20 | .544 | 905 | 306 | | - .022 | 10:45 | |
| 5 | 20 | .544 | 905 | 306 | | - .022 | 11:40 | |
| 6 | 20 | .544 | 905 | 306 | | - .020 | 2:25 | |
| 7 | 25 | .544 | 905 | 306 | | - .020 | 3:05 | |
| 8 | 25 | .544 | 904 | 305 | | - .020 | 3:35 | |
| 9 | 25 | .542 | 903 | 306 | | - .021 | 8:45 | |
| 10 | 50 | .533 | 897 | 310 | | - .045 | 9:45 | |
| 11 | 50 | .533 | 897 | 310 | | - .046 | 10:15 | |
| 12 | 50 | .531 | 895 | 310 | | - .045 | 1:50 | |
| 13 | 70 | .495 | 874 | 329 | | - .170 | 9:30 | |
| 14 | 70 | .493 | 871 | 328 | | - .168 | 10:00 | |
| 15 | 70 | .484 | 859 | 326 | ↓ | - .151 | 11:45 | ↓ |

## TABLE 8. LAMP OPERATING CHARACTERISTICS

Lamp: Scientific Services, 10.0 eV, SN 2129

| RUN # | TEMP. (C°) | Vi (Volts) | LAMP SUPPLY (Volts) | LAMP VOLTAGE (Volts) | DET. BIAS (Volts) | DET. OUTPUT (Volts) | TIME OF MEAS. | DATE |
|---|---|---|---|---|---|---|---|---|
| 1 | 19 | .142 | 769 | 613 | 147 | - .034 | 9:40 | 11-20-84 |
| 2 | 19 | .142 | 763 | 605 | | - .031 | 10:15 | |
| 1 | 0 | .120 | 745 | 613 | | - .012 | 1:15 | |
| 2 | 0 | .118 | 745 | 615 | | - .011 | 1:45 | |
| 3 | 0 | .116 | 744 | 616 | | - .010 | 2:15 | |
| 4 | 20 | .129 | 754 | 612 | | - .014 | 3:00 | |
| 5 | 20 | .129 | 755 | 613 | | - .014 | 3:30 | |
| 6 | 20 | .127 | 745 | 605 | | - .013 | 4:00 | ↓ |
| 7 | 25 | .129 | 754 | 612 | | - .014 | 9:50 | 11-21-84 |
| 8 | 25 | .127 | 744 | 604 | | - .013 | 10:20 | |
| 9 | 25 | .126 | 748 | 609 | | - .012 | 10:50 | |
| 10 | 50 | .128 | 764 | 623 | | - .014 | 10:15 | |
| 11 | 50 | .126 | 762 | 623 | | - .013 | 10:45 | |
| 12 | 50 | .126 | 751 | 612 | | - .012 | 11:30 | |
| 13 | 70 | .110 | 783 | 662 | | - .024 | 11:50 | |
| 14 | 70 | .101 | 767 | 656 | | - .024 | 12:30 | |
| 15 | 70 | .113 | 777 | 653 | ↓ | - .023 | 1:00 | ↓ |